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(NASA-CR-147640) FLOW VISUALIZATION TESTS OF A 0.004-SCALE SPACE SHUTTLE VEHICLE 2A MODEL (NO. 13-OTS) IN THE MSFC 14-INCH TRISONIC WIND TUNNEL (IS6A) (Chrysler Corp.) 37 p HC A03/MF A01 CSCL 02A G3/16

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SPACE SHUTTLE

AEROTHERMODYNAMIC DATA REPORT

JOHNSON SPACE CENTER

HOUSTON, TEXAS

DATA MANagement services

SPACE DIVISION CHRYSLER CORPORATION

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FLOW VISUALIZATION TESTS OF A 0.004-SCALE SPACE SHUTTLE VEHICLE 2A MODEL (NO. 13-OTS) IN THE MSFC 14-INCH TRISONIC WIND TUNNEL (IS6A)

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Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas

WIND TUNNEL TEST SPECIFICS:

Test Number: MSFC TWT 582
NASA Series Number: IS6A
Model Number: 13-OTS
Test Dates: October 2 through October 11, 1973
Occupancy Hours: 76

FACILITY COORDINATOR:

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SPACE SHUTTLE VEHICLE 2A MODEL (NO. 13-OTS)

IN THE MSFC 14-INCH TRISONIC WIND TUNNEL (IS6A)

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ABSTRACT

Documented are representative photographs of surface flow patterns, created by oil flow and shadowgraph techniques, obtained during wind tunnel tests of an 0.004-scale version of the 2A Rockwell International SSV Orbiter. The purpose of this test series was to obtain flow visualization photographs to aid in interpretation of test IS1 aero-noise data. The test was designated IS6A and conducted during October 1973 at nominal Mach numbers from 0.6 to 3.48. The Orbiter was run in proximity to the external tank and solid rocket boosters at angles of attack from -5° to +9° at 0° angle of sideslip.

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INTRODUCTION

A definition of aerodynamic flow fields is a requisite for interpretation of aero-noise environment data. The interpretation of the aero-noise data from test series IS1 required that a reasonably accurate determination of viscous effects, interactions, separations, and shocks present in the flow field be obtained. Since analytical methods were not sufficiently accurate to describe the flow field,flow visualization tests were required.

To meet this need, test series IS6A was conducted. To adequately describe the field, both oil flow visualization photographs and shadowgraphs were obtained for correlation with the IS1 data and to approximate the extent of the nonsteady pressure fields.

A complete set of shadowgraph and color oil flow photographic data is in the possession of this person:

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NOMENCLATURE

Symbol	Mnemonic	Description
α	ALPHA	angle of attack of model measured from the orbiter fuselage reference plane; degrees, positive nose up
β	BETA	angle of sideslip measured from orbiter centerline; degrees, positive nose left
M	MACH	freestream Mach number

CONFIGURATIONS INVESTIGATED

Model 13-OTS was a 0.004-scale version of the Rockwell International Space Shuttle integrated vehicle which was designed primarily for force testing. The orbiter (designated 13-0) was constructed of aluminum, stainless steel, and Stycast. Except for elevons, the lower mid-body and wing were constructed of aluminum while the OMS pods were of Stycast, a proprietary catalytic setting resin. The remainder of the orbiter was stainless steel. The model represented configuration 2A with the nose modified to reflect configuration 3. This model was fabricated by Lockheed Missile and Space Company at Huntsville, Alabama.

The external tank (ET), designated MSFC model 451, was fabricated of stainless steel. The front attach lug from the ET to solid rocket booster (SRB) was simulated on the left side only. The orbiter to ET struts were simulated with .044 inch diameter wire. The ET longitudinal plumbing lines, cable trays, and detail protuberances were unsimulated.

The SRB (S7) was fabricated of stainless steel by modifying the old S_3 booster. During testing, however, MSFC engineers referred to the S_7 booster as the S_3 (see figures 4 and 5). Detail protuberances are unsimulated. The 259" nozzle shroud and an aft ET ring are provided.

Model dimensional data and nomenclature are presented in Table III. The configuration tested was B_{27} C_5 W_{87} E_{18} M_3 V_7 R_5 F_4 T_9 S_7, referred to in the data photographs as T_9 O_{13} S_3. The component nomenclature O_{13} in figures 4 and 5 is an MSFC designation for the Rockwell International 13-0 force model.

CONFIGURATIONS INVESTIGATED (Concluded)

As part of the model installation, a careful inspection was made and all cracks, screw heads, and other surface discontinuities were filled with "body filler" and sanded before the several thin coats of neutral grey lacquer were applied. Particular care was taken to insure a good surface, and this finish was inspected and repaired at the conclusion of the day's running to provide a fresh quality surface for the next day.

Model was installed using a dual sting arrangement with the orbiter on one sting and the integral ET and SRBs on a three-pronged second sting. Each sting was separately removable so that photographs of either the orbiter or ET/SRB combination could be easily made.

Artificial boundary layer transition (#100 grit in 1/8" wide strips) was used during runs 204, 205, 206, 207, 208, and 209. No significant difference in oil flow patterns was noted. This was as expected since the paint beads were of considerably larger (on the order of 10 times) size than the grit and probably initiated transition.

Used was the following nomenclature:

O_{13}	orbiter, B_{27} C_5 W_{87} E_{18} M_3 V_7 R_5 F_4
T_9	ET, T_9
S_7	SRB, S_7

INSTRUMENTATION

Tunnel parameter information was garnered utilizing a total temperature and total pressure sensors in the settling chamber. When the transonic section was utilized, the static pressure was measured by a transducer located in the bottom of the test section beneath the perforated walls. The static pressure for supersonic test conditions was calculated based on the mach number.

A 4" x 5" Calumet view camera with a 160mm f5.6 Schneider lens was used with a 10-second exposure on Ektacolor film. One 3200°K photoflood provided the required illumination.

The camera was mounted in a keyed swing-away frame by the side of the tunnel at the rear of the test section. This arrangement allowed the camera to be away from the test section door and window so that the shadowgraphs could be taken during the blow. After the run, the tunnel was opened and the camera was swung into position to take the photographs of the oil flow without disturbing the model. The keyed arrangement allowed the camera to be returned to the same place each time. Since the model position did not change, no adjustment of the camera setup was required from run to run.

TEST FACILITY DESCRIPTION

The Marshall Space Flight Center 14" x 14" Trisonic Wind Tunnel is an intermittent blowdown tunnel which operates by high pressure air flowing from storage to either vacuum or atmospheric conditions. A Mach number range from .2 to 5.85 is covered by utilizing two interchangeable test sections. The transonic section permits testing at Mach 0.20 through 2.50, and the supersonic section permits testing at Mach 2.74 through 5.85. Mach numbers between .2 and .9 are obtained by using a controllable diffuser. The range from .95 to 1.3 is achieved through the use of plenum suction and perforated walls. Mach numbers of 1.44, 1.93, and 2.50 are produced by interchangeable sets of fixed contour nozzle blocks; the M = 2.50 blocks are not particularly satisfactory. Above Mach 2.50 a set of fixed contour nozzle blocks are tilted and translated automatically to produce any desired Mach number, calibration is in .25 Mach increments.

Air is supplied to a 6000 cubic foot storage tank at approximately -40°F dew point and 500 psi. The compressor is a three-stage reciprocating unit driven by a 1500 hp motor.

The tunnel flow is established and controlled with a servo actuated gate valve. The controlled air flows through the valve diffuser into the stilling chamber and heat exchanger where the air temperature can be controlled from ambient to approximately 180°F. The air then passes through the test section which contains the nozzle blocks and test region.

Downstream of the test section is a hydraulically controlled pitch sector that provides a total angle of attack range of 20° (±10°). Sting

offsets are available for obtaining various maximum angles of attack up to 90°.

TEST PROCEDURE

The integrated vehicle was tested through a range of nominal Mach numbers from 0.6 to 3.48. The test conditions are detailed in the run schedule and in the tabulated tunnel parameter data (Table I).

The collection of oil flow data photographs was performed as follows:

The model was visually inspected for deterioration of the prepainted surface prior to each run. A pattern of dots of artist's oil pigments and linseed oil was supplied to the model with hypodermic syringes in 8 longitudinal rows on the ET and SRB and in a modified longitudinal pattern on the orbiter (see figure 3). Paint application was made to the ET/SRB assembly and to the orbiter separately; then the two were assembled and placed on the tunnel sector.

Each of the three components, orbiter, ET, and SRB, was prepared with a different primary color pigment, alternating rows with white. The colors used were medium green and white on the SRBs, medium red and white on the ET, and medium blue and white on the orbiter. The particular blue used, prussian blue, was found to be a very strong tinting color, and to avoid it completely washing out the rows of white pigment, it was thinned four parts white to one of blue before it was applied.

The viscosity of the oil paint was tailored to the variation in free stream density with Mach number, a lower viscosity being required as Mach increased. Satisfactory flowing was obtained with the following mixtures:

TEST PROCEDURE (Concluded)

Pigment (Parts)	Linseed Oil (Parts)	Mach No.
1	1	0.6 to 1.2
1	1.5 to 2.0	1.4 to 2.0
1	2.5 to 3.5	2.5 to 3.5

The tunnel was closed, the run made, and shadowgraphs taken. The tunnel was operated for approximately five seconds after stable flow conditions were attained.

The tunnel was then opened, the ET/SRB removed, and photographs of the orbiter top side and bottom made. Subsequently the ET/SRB was replaced and the orbiter removed and photographs of the top and side made.

Model was washed with mineral spirits after each run.

During the transonic portion of the test, two runs were made at each test condition. The first was made with the porous walls in place to obtain the best possible flow conditions, and it was with these walls that the oil flows were obtained. The second was made to obtain shadowgraphs. During shadowgraph runs the glass instead of porous walls were used. In the higher Mach regime where shock reflection was not a problem, the glass walls were used for all runs to allow both oil flows and shadowgraphs to be obtained at the same time.

DISCUSSION OF RESULTS

A listing of runs and data obtained is shown in Table II.

Figures 3 and 4 present a representative set of oil flow photographs. The originals are 8 1/2" x 11" color prints.

Figures 5 and 6 present typical shadowgraphs obtained in this test series.

It should be noted that the artist's paint formed a layer of significant thickness on the 0.004 scale-model and therefore degraded the accuracy of the model contours. The paint thickness is estimated as varying from zero at the nose to 0.020 inch (0.5 mm) near the aft end of the model and in areas of vortex flow. Accordingly, care should be exercised in the use of oil flow photographs or shadowgraphs made during the presence of paint on the model.

Examination of the data photographs indicates a trend to flow angularity between the external tank (ET) and the lower surface of the orbiter; in some cases this deflection from the free stream exceeds 10° (run 4/1, bottom of orbiter). This anomaly can be traced to the omission of a simulated front SRB attach strut on the right hand side of the external tank, the model having been intentionally built to this configuration. The model of test IS1 was not assymetric; therefore, care should be exercised in interpreting the data photographs.

REFERENCES

1. Herrera, B. J. "Pretest Information for Flow Vizualization Test (IS-6) of the 0.004-Scale Space Shuttle Integrated Vehicle Model in the MSFC TWT," Rockwell International Report SD73-SH-0258, October 1, 1973.

2, Herrera, B. J. "Pretest Information for Tests of the 0.040-Scale Space Shuttle Vehicle Aerodynamic Noise Model 11-OTS in the Ames Research Center Unitary Plan Wind Tunnels," Rockwell International Report SD73-SH-0136, May 11, 1973.

3. J. P. Reding ET Al. "Unsteady Aerodynamic Analysis of the Space Shuttle Vehicle," Lockheed Missile and Space Company Report D352320, August 73.

TABLE I.

TEST : IS6A

DATE :

TEST CONDITIONS

MACH NUMBER	REYNOLDS NUMBER (per foot)	DYNAMIC PRESSURE (pounds/sq. inch)	STAGNATION TEMPERATURE (degrees Fahrenheit)
0.6	5.0×10^6	4.35	100
0.7	5.6×10^6	5.40	100
0.8	6.0×10^6	6.45	100
0.85	6.1×10^6	6.92	100
0.9	6.2×10^6	7.36	100
0.95	6.4×10^6	7.74	100
1.0	6.5×10^6	8.14	100
1.10	6.6×10^6	9.29	100
1.20	6.7×10^6	10.68	100
1.46	6.5×10^6	9.47	100
1.96	7.0×10^6	10.20	100
2.99	4.0×10^6	5.19	100
3.27	12.6×10^6	13.6	100
3.48	11.2×10^6	11.0	100

BALANCE UTILIZED: None

	CAPACITY:	ACCURACY:	COEFFICIENT TOLERANCE:
NF			
SF			
AF			
PM			
RM			
YM			

COMMENTS:

TABLE II.

TEST: I S6A	DATA SET/RUN NUMBER COLLATION SUMMARY	DATE:

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	GRIT	0.6	0.7	0.8	0.85	0.9	0.95	1.0	1.10	1.20	1.46	1.96	2.99	3.27	5.48
RIB001	$T_9 O_{13} S_7$	0	0	OFF	O S 1	O S 2	O S 3	O S 4	O S 5	O S 6	O S 7	O S 8	O S 9	O S 37	O S 50	O S 52	O S 58	O S 59
02					S 1/1			O 4/1	O 5/1	O 6/1	O 7/1	O 8/1				O S 52/1		
3												O 8/2						
4								O 210	O 211	O 212	O 213	O 214	O 215					
5				ON				O 204	O 205	O 206	O 207	O 209	O 209					
6		-.3		OFF													O 51 S	
7		-.76																O 60 S
8		1.26										O 11	O 10	O 38 S	O 51 S			
9		1.26										11/1 S	10/1 S	38/1 S				
10		1.40									O 12							
11		1.40									12/1 S							
12		1.50								O 13								
13		1.50								13/1 S								
14		1.60							O 14									
15		1.60							14/1 S									
16		1.72						O 15										
17		1.72						15/1 S										
18		1.82					O 16											

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

α OR β SCHEDULES

COEFFICIENTS

O = Oil flow Photographs

S = Shadowgraph

IDVAR (1) IDVAR (2) NDV

TABLE II. - Concluded.

TEST: IS6A

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE:

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	GRIT	0.6	0.7	0.8	0.85	0.9	0.95	1.0	1.10	1.20	1.46	1.96	2.99	3.27	3.48
RIB019	T9 Q13 S7	1.82	0	OFF			16/1 S											
20		2.06				O 17												
21		2.06				17/1 S												
22		2.32			O 15													
23		2.32			18/1 S													
24		5			O 19	O 21	O 23	O 25	O 27	O 29	O 31	O 33	O 35	O 39 S	O 49 S	O 53 S	O 56 S	O 61 S
25													O 35/1					
26				ON								O 216						
27				OFF	19/1 S	21/1 S	23/1 S	25/1 S	27/1 S	29/1 S	31/1 S	33/1 S	35/2 S					
28		-5			O 20	O 22	O 24	O 26	O 28	O 30	O 32	O 34	O 36	O 40 S	O 43 S	O 54 S	O 56 S	O 62 S
29		1			20/1 S	22/1 S	24/1 S	26/1 S	28/1 S	30/1 S	32/1 S	34/1 S	36/1 S					
30	MODEL ROLLED	0	0		81 S	82 S	83 S	84 S	85 S	86 S	87 S	88 S	89 S	42 S	47 S	65 S	64 S	63 S
31		5	0		98 S	97 S	96 S	95 S	94 S	93 S	92 S	91 S	90 S	44 S	45 S	66 S	68 S	67 S
32		-5	0		99 S	100 S	101 S	102 S	103 S	104 S	105 S	106 S	107 S	43 S	46 S	71 S	69 S	70 S
33		9	0		O 72 S	O 73 S	O 74 S	75 S	76 S	77 S	78 S	79 S	O 80 S	O 41 S				
34		9						O 75/1	O 76/1	O 77/1	O 78/1	O 79/1						

TEST RUN NUMBERS

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS

α OR β SCHEDULES

O = OIL FLOW PHOTOGRAPHS

S = SHADOWGRAPH

IDVAR (1) IDVAR (2) NDV

TABLE III. - MODEL DIMENSIONAL DATA

MODEL COMPONENT: BODY B27

GENERAL DESCRIPTION: Fuselage, 2A Configuration, lightweight orbiter, per Rockwell lines VL 70 000089B Nose recontoured forward of X_o=299 to VL 70 000139 forebody contour.

Scale Model = .004

DRAWING NUMBER: VL 70 000089B, 92, 93, 94A
VL 70 000139

DIMENSION:	FULL SCALE	MODEL SCALE
Length	1290.3	5.1612
Max Width--in. @ X_o = 1528.3	265.0	1.060
Max Depth --in. @ X = 1480.52	248.0	0.992
Fineness Ratio	5.012	5.012
Area		
Max Cross-Sectional	456.4	1.826
Planform		
Wetted		
Base		

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TABLE III. - Continued.

MODEL COMPONENT: CANOPY - C5

GENERAL DESCRIPTION: 2A Configuration per Lines VL70-000092

Scale Model = .004

DRAWING NUMBER VL70-000092

DIMENSION:	FULL SCALE	MODEL SCALE
Length (Sta Fwd Bulkhead)	391.0	1.564
Max Width (T.F. Bulkhead)	560.0	2.240
Max Depth (WPZ. = 421.922 to Z. = 500)		
Fineness Ratio		
Area		
Max Cross-Sectional		
Planform		
Wetted		
Base		

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MODEL COMPONENT: ELEVON E-18

GENERAL DESCRIPTION: 2A Configuration per W-87 Rockwell Lines VL70-000093 data for (1) of (2) sides

Scale Model =

DRAWING NUMBER: VL70-000093

DIMENSIONS:	FULL-SCALE	MODEL SCALE
Area - FT^2	205.52	0.003
Span (equivalent) - IN.	353.34	1.413
Inb'd equivalent chord	114.78	0.459
Outb'd equivalent chord	55.00	0.220
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	.208	.208
At Outb'd equiv. chord	.400	.400
Sweep Back Angles, degrees		
Leading Edge	0.00	0.00
Tailing Edge	-10.24	-10.24
Hingeline	0.00	0.00
Area Moment (Normal to hinge line) - FT^3 Product of Area Moment	1548.07	.0001

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TABLE III. - Continued.

MODEL COMPONENT: F4 BODY FLAP

GENERAL DESCRIPTION: 2A Configuration per Rockwell Lines VL70-000094A

Scale Model = .004

DRAWING NUMBER VL70-000094A

DIMENSION:	FULL SCALE	MODEL SCALE
Length	84.70	0.339
Max Width	265.00	1.060
Max Depth		
Fineness Ratio		
Area - FT^2		
Max Cross-Sectional		
Planform	142.64	0.571
Wetted		
Base	38.65	0.006

TABLE III. - Continued.

MODEL COMPONENT: OMS POD - M3

GENERAL DESCRIPTION: 2A Lightweight Configuration per Rockwell Lines VL70-000094A

Scale Model = .004

DRAWING NUMBER VL70-000094A

DIMENSION:	FULL SCALE	MODEL SCALE
Length	346.0	1.384
Max Width $X_o = 1450.0$	108.0	0.432
Max Depth $X_o = 1500.0$	113.0	0.452
Fineness Ratio		
Area		
Max Cross-Sectional		
Planform		
Wetted		
Base		

℄ OF OMS POD
WP = 463.9 INFS; WP 400 + 63.9 = 463.9
BP = 80.0 INFS
LENGTH 1214.0 to 1560.0 = 346.0 INFS

TABLE III. - Continued.

MODEL COMPONENT: RUDDER - R5

GENERAL DESCRIPTION: 2A, 3 and 3A Configuration per Rockwell Lines VL70-000095

Model Scale = .004

DRAWING NUMBER: VL70-000095

DIMENSIONS:	FULL-SCALE	MODEL SCALE
Area - FT^2	106.38	0.017
Span (equivalent) - IN.	201.0	0.804
Inb'd equivalent chord	91.585	0.366
Outb'd equivalent chord	50.833	0.203
Ratio movable surface chord/ total surface chord		
At Inb'd equiv. chord	0.400	0.400
At Outb'd equiv. chord	0.400	0.400
Sweep Back Angles, degrees		
Leading Edge	34.83	34.83
Tailing Edge	26.25	26.25
Hingeline	34.83	34.83
Area Moment (Normal to hinge line)- FT^3 Product of Area and Mean Chord	526.13	0.00003

TABLE III. - Continued.

MODEL COMPONENT: BOOSTER SOLID ROCKET MOTOR - S_7

GENERAL DESCRIPTION: Light weight Orbiter configuration (S_6) shifted forward 71 inches full scale

Model Scale = .004

DRAWING NUMBER VL72-000061C (mod.)
VL77-000012B (mod.)

DIMENSION:	FULL SCALE	MODEL SCALE
Length (Includes Nozzle) - IN.	1741.0	6.964
Max Width (Tank Dia) - IN.	142.3	0.5962
Max Depth (Aft Shroud) - IN.	259.0	1.036
Fineness Ratio	6.722	6.722
Area - FT^2		
Max Cross-Sectional	365.87	1.503
Planform		
Wetted		
Base		
WP of BSRM Centerline (Z_T) - IN.	400	1.6
FS of BSRM Nose (X_T) - IN.	672.0	2.688

TABLE III. - Continued.

MODEL COMPONENT: EXTERNAL TANK - T9

GENERAL DESCRIPTION: 2A Configuration

NOTE: T9 identical to T8 W/O retro pkg., nose w/30"R F.S.

Model Scale = .004

DRAWING NUMBER

DIMENSION:	FULL SCALE	MODEL SCALE
Length - IN.	1858	7.432
Max Width (Dia) - IN.	324.0	1.296
Max Depth		
Fineness Ratio L/D	5.73457	5.73457
Area - FT^2		
Max Cross-Sectional	572.56	0.00916
Planform		
Wetted		
Base		

TABLE III. - Continued.

MODEL COMPONENT: VERTICAL - V_7

GENERAL DESCRIPTION: Centerline vertical tail, double-wedge airfoil with rounded leading edge.

NOTE: Same as V_5, but with manipulator housing removed.

MODEL SCALE: .004

DRAWING NUMBER: VL70-00 139

DIMENSIONS:

TOTAL DATA

	FULL-SCALE	MODEL SCALE
Area (Theo) Ft^2		
Planform	425.92	0.007
Span (Theo) In	315.72	1.263
Aspect Ratio	1.675	1.675
Rate of Taper	0.507	0.507
Taper Ratio	0.404	0.404
Sweep Back Angles, degrees		
Leading Edge	45.000	45.000
Trailing Edge	26.249	26.249
0.25 Element Line	41.130	41.130
Chords:		
Root (Theo) WP	268.50	1.074
Tip (Theo) WP	108.47	0.434
MAC	199.81	0.799
Fus. Sta. of .25 MAC	1463.50	5.954
W. P. of .25 MAC	635.522	2.542
B. L. of .25 MAC	0.00	0.000
Airfoil Section		
Leading Wedge Angle Deg	10.000	10.000
Trailing Wedge Angle Deg	14.920	14.920
Leading Edge Radius	2.0	2.0
Void Area	13.17	0.0002
Blanketed Area	0.00	0.00

TABLE III. - Concluded.

MODEL COMPONENT: WING-W 87 New Lightweight Orbiter

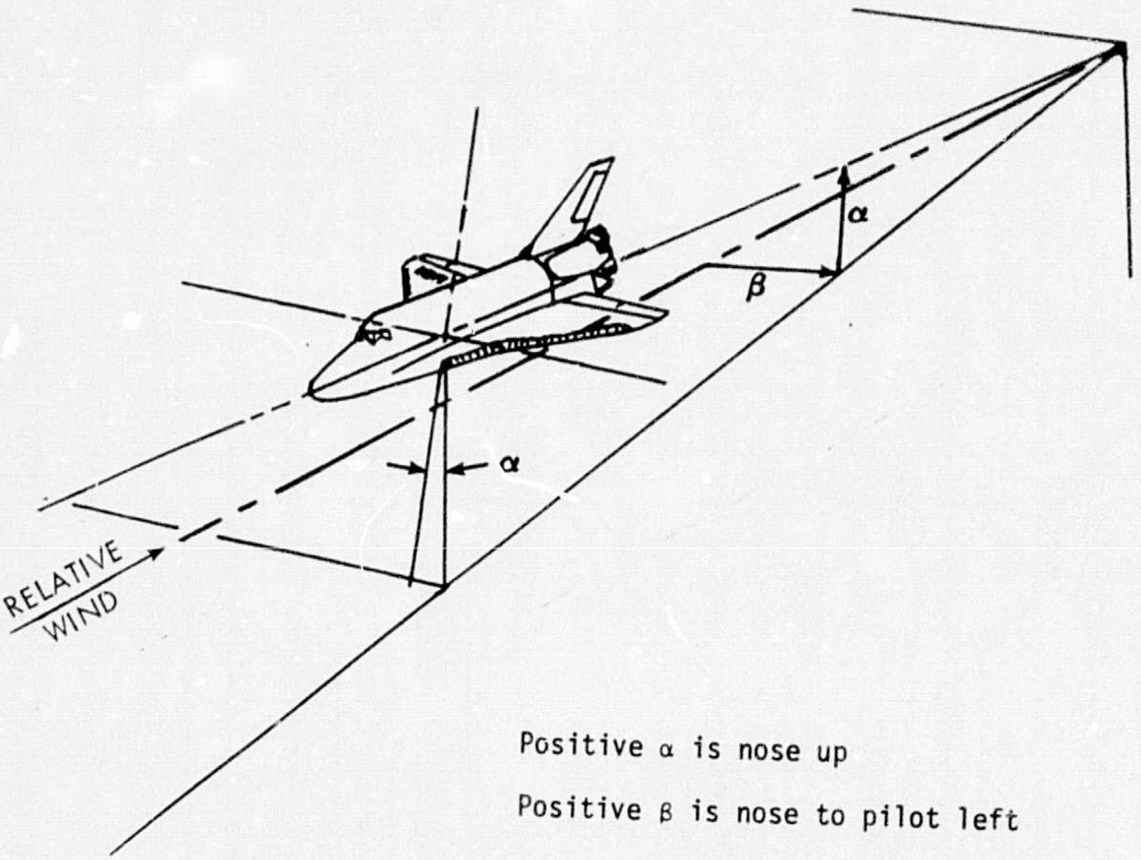
GENERAL DESCRIPTION: Orbiter Configuration per Lines VL70-000093

(NOTE: Dihedral angle is defined at the lower surface of the wing at the 75.33% element line projected into a plane perpendicular to the FRL)

Scale Model = .004

TEST NO.   DWG. NO. VL70-000093

DIMENSIONS:	FULL-SCALE	MODEL SCALE
TOTAL DATA		
Area (Theo.) Ft^2		
Planform	2690.00	0.043
Span (Theo In.	936.68	3.747
Aspect Ratio	2.265	2.265
Rate of Taper	1.177	1.177
Taper Ratio	0.200	0.200
Dihedral Angle, degrees	3.500	3.500
Incidence Angle, degrees	3.000	3.000
Aerodynamic Twist, degrees	+3.000	+3.000
Sweep Back Angles, degrees		
Leading Edge	45.000	45.000
Trailing Edge	-10.24	-10.24
0.25 Element Line	35.209	35.209
Chords:		
Root (Theo) B.P.O.O.	689.24	2.757
Tip, (Theo) B.P. 468.341	137.85	0.551
MAC	474.81	1.889
Fus. Sta. of .25 MAC	1136.89	4.548
W.P. of .25 MAC	299.20	1.197
B.L. of .25 MAC	182.13	0.728
EXPOSED DATA		
Area (Theo) Ft^2	1752.29	0.028
Span, (Theo) In. BP108 to 468.341	720.68	2.883
Aspect Ratio	2.058	2.058
Taper Ratio	0.2451	0.2451
Chords		
Root BP108	562.40	2.250
Tip 1.00 $\frac{b}{2}$	137.85	0.551
MAC	393.03	1.572
Fus. Sta. of .25 MAC	1185.31	4.741
W.P. of .25 MAC	300.20	1.201
B.L. of .25 MAC	251.76	0.575
Airfoil Section (Rockwell Mod NASA) XXXX-64		
Root $\frac{b}{2}$ = .425	0.10	0.10
Tip $\frac{b}{2}$ = 1.00	0.12	0.12
Data for (1) of (2) Sides		
Leading Edge Cuff		
Planform Area Ft^2	120.33	0.0019
Leading Edge Intersects Fus M. L. @ Sta	560.0	2.240
Leading Edge Intersects Wing @ Sta	1035.0	4.4



Positive α is nose up

Positive β is nose to pilot left

Figure 1. - Axis Systems.

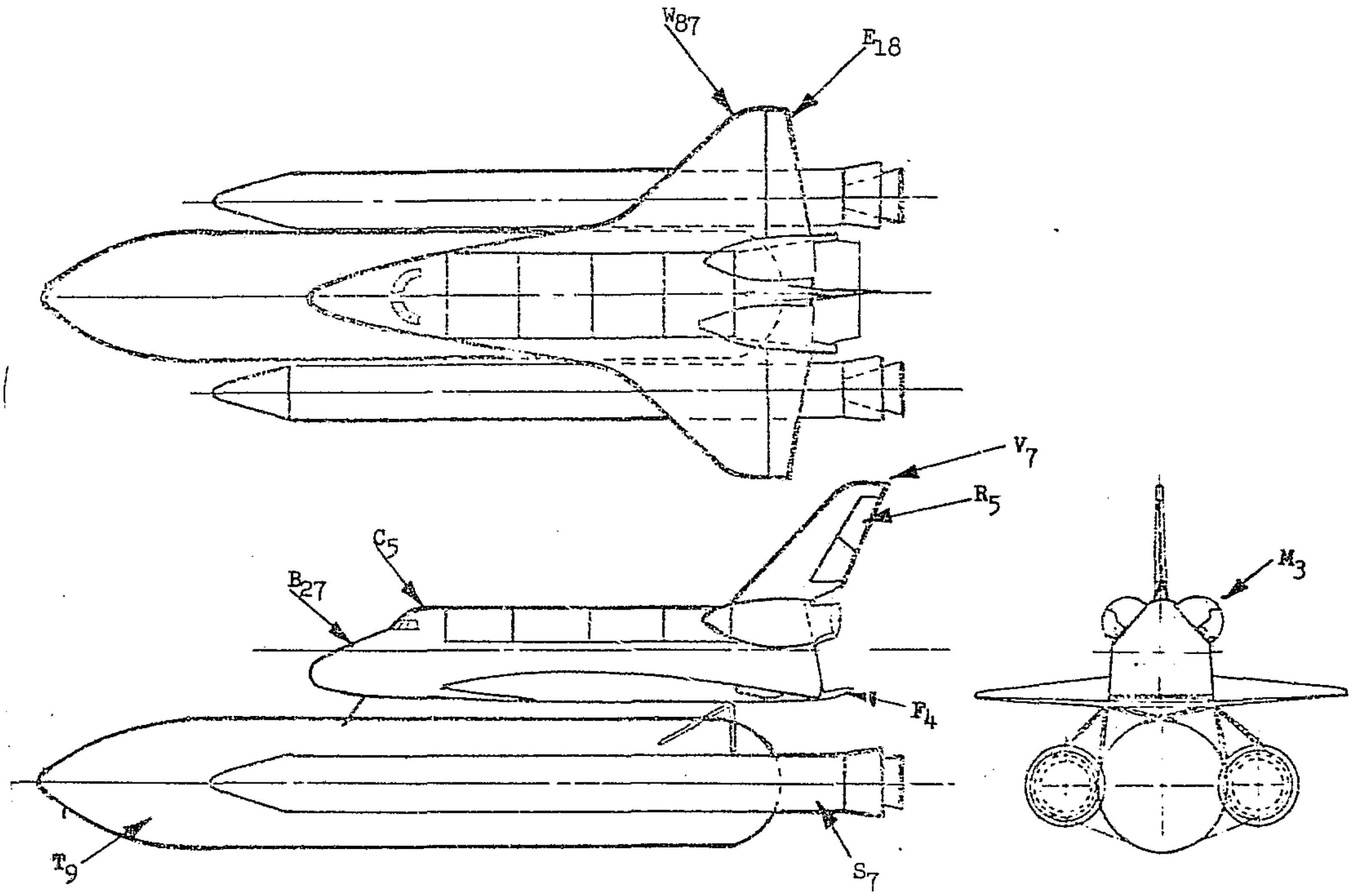
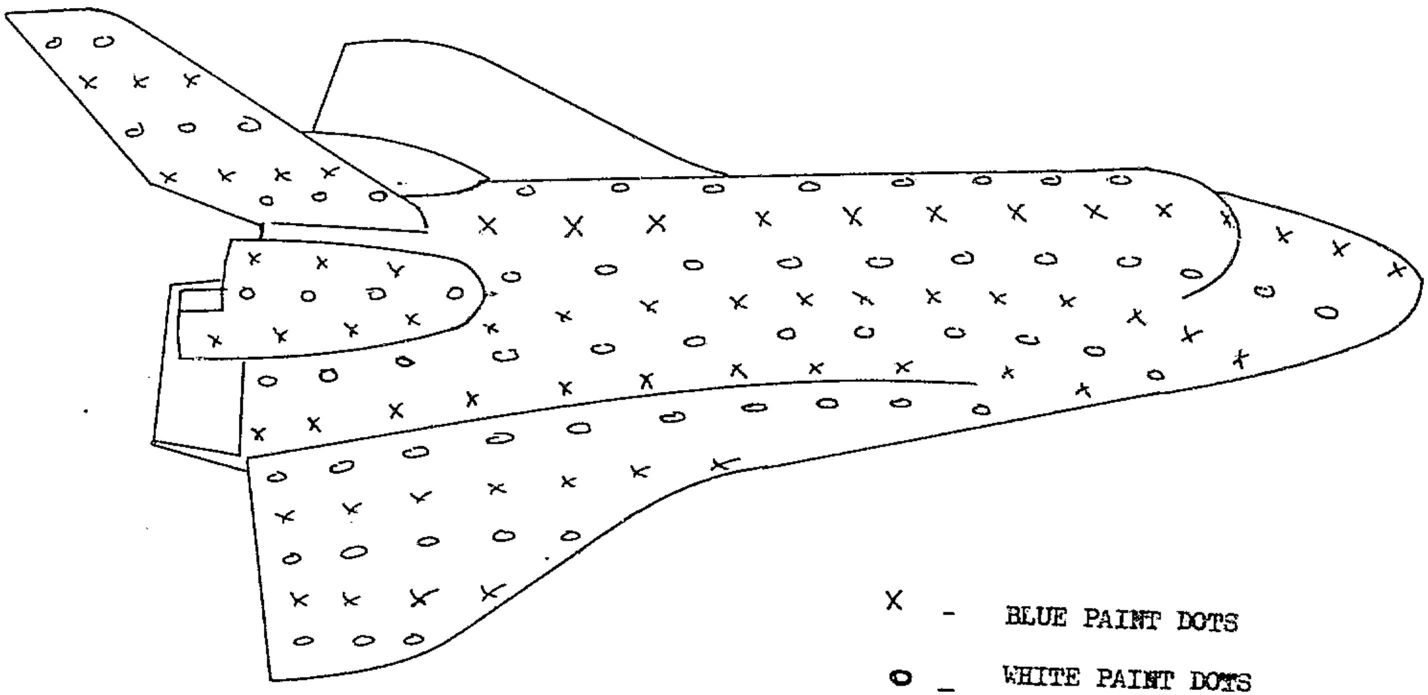


Figure 2. - General Arrangement of Integrated Vehicle Model



X - BLUE PAINT DOTS

O _ WHITE PAINT DOTS

Paint array shown on right hand side only

Figure 3. - Typical Orbiter Oil Dot Pattern.

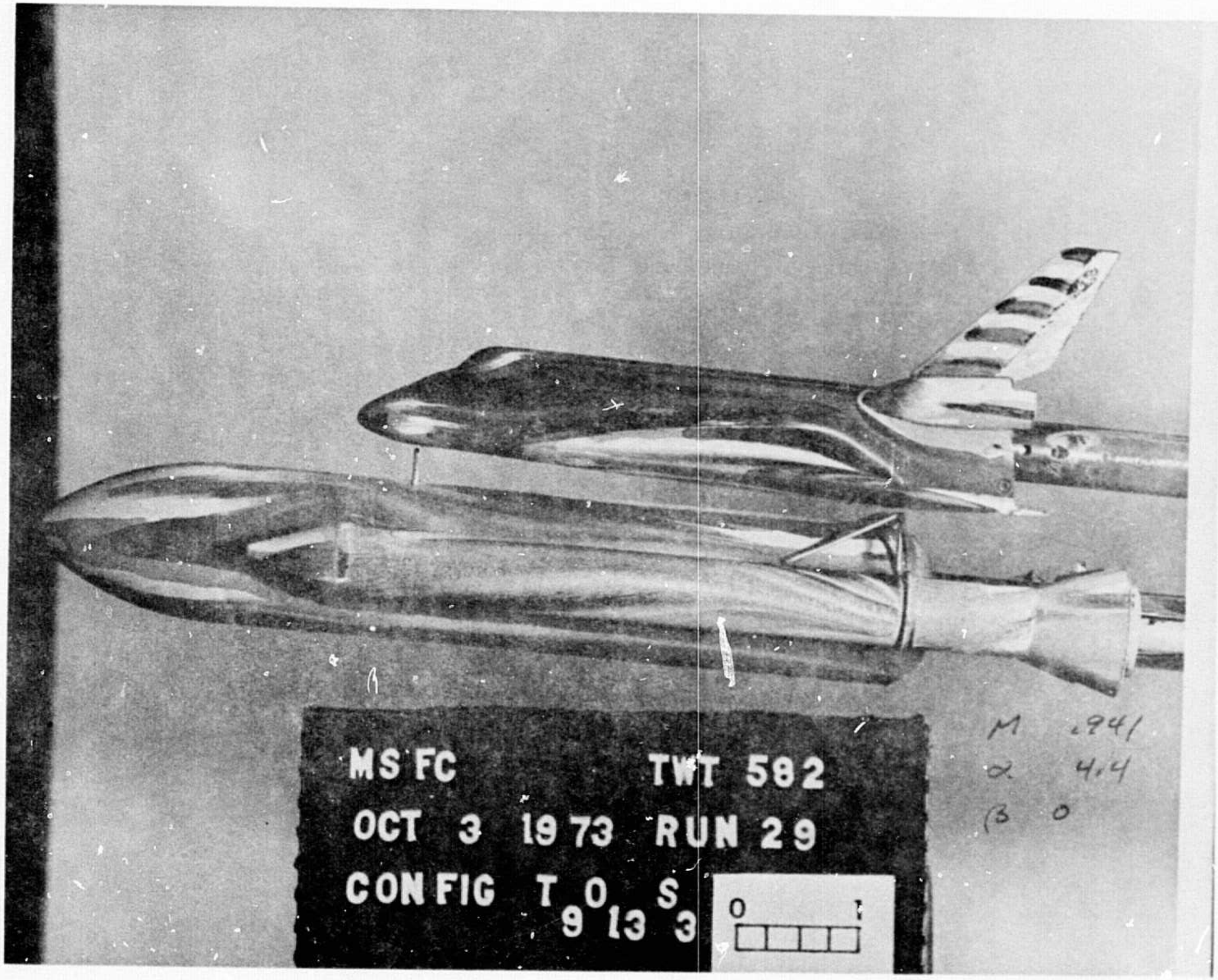


Figure 4. Oil Flow Photograph of Integrated Vehicle, $\alpha = 4.4$, $\beta = 0$, $M = 0.95$ (Typical of Side Photographs).

Figure 5. - Oil Flow Photograph of Orbiter Upper Surface, α = 4.84, β = 0, M = 0.85 (Typical).

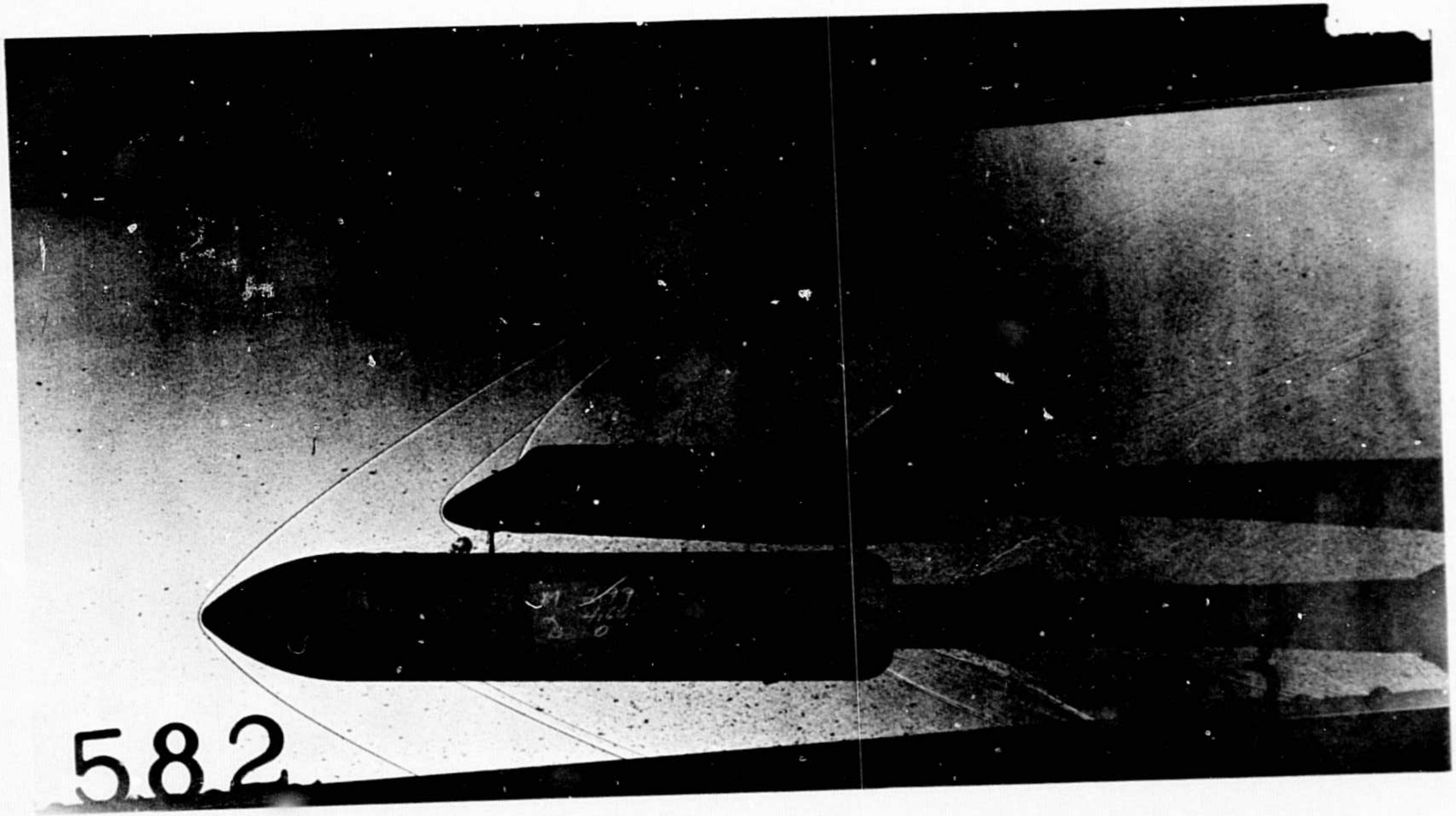


Figure 6. - Shadowgraph of Integrated Vehicle, α = 4.66, β = 0, M = 2.99, Side View.

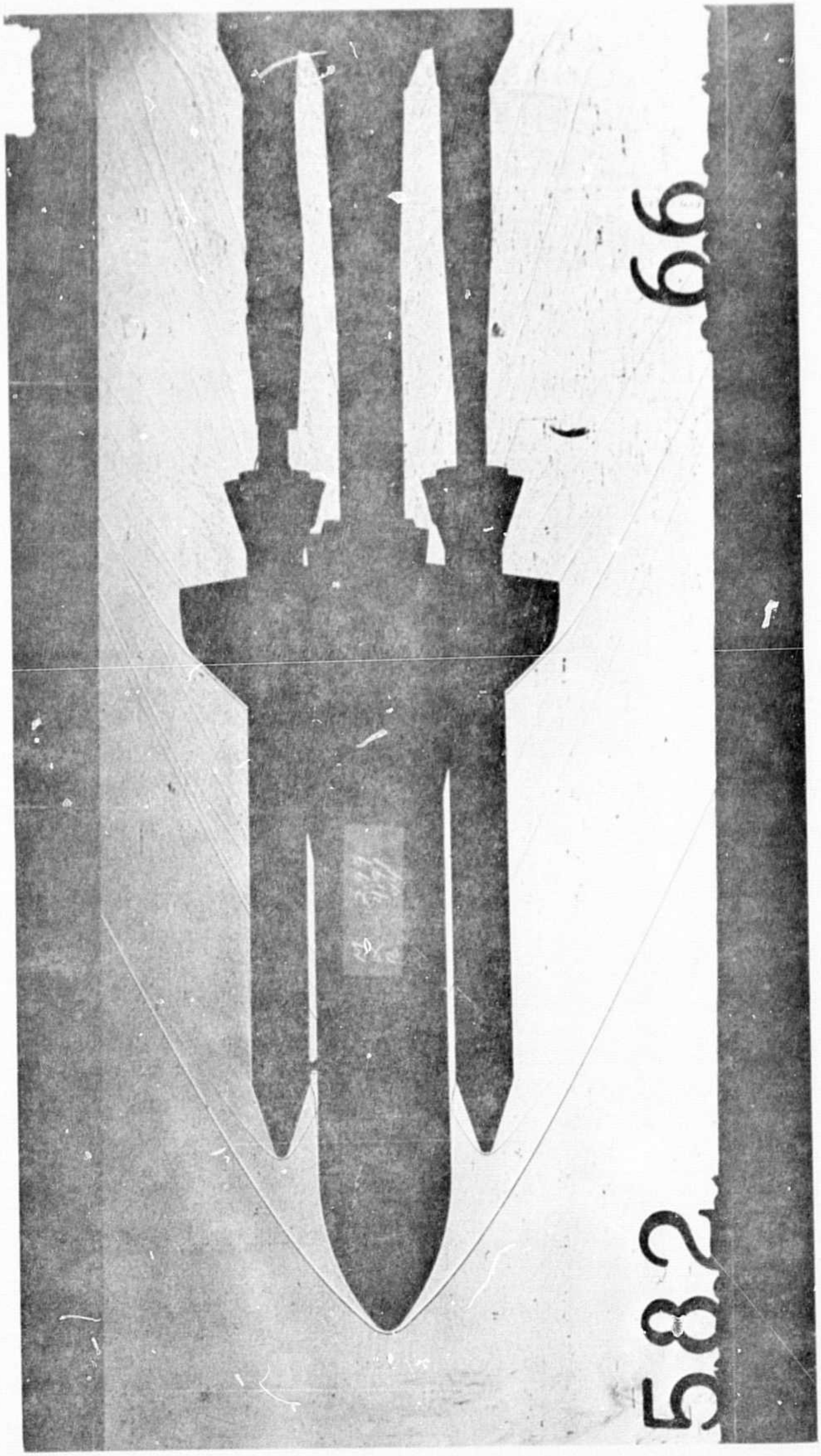


Figure 7. - Shadowgraph of Integrated Vehicle, α = 4.91, β = 0, M = 2.99, Bottom View.